MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2015/2016

EEE1046 – ELECTRONICS III

(All sections / Groups)

3 JUNE 2016
3:00 PM – 5:00 PM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages (including the cover page) with 4 Questions only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) An ideal operational amplifier (op-amp) has characteristics that are different from a practical op-amp.

(i) State **TWO** ideal characteristic of an op-amp and **TWO** fundamental rules used in the analysis of an ideal op-amp as a result of the ideal characteristic assumptions. [2+2 marks]

(ii) Sketch a basic ideal inverting op-amp. Label the input resistor R_1, feedback resistor R_F, input voltage V_i and output voltage V_o accordingly. [4 marks]

(iii) With the aid of the sketch in Part (a)(ii), derive the equation for the closed loop gain of the ideal inverting amplifier. [6 marks]

(b) An ideal op-amp circuit with feedback resistor 10 kΩ, input voltages 10 V and 5 V with resistors 20 kΩ at the inverting input is shown in Figure Q1(a). Determine the feedback current I_F and the output voltage V_{out}. [3+2 marks]

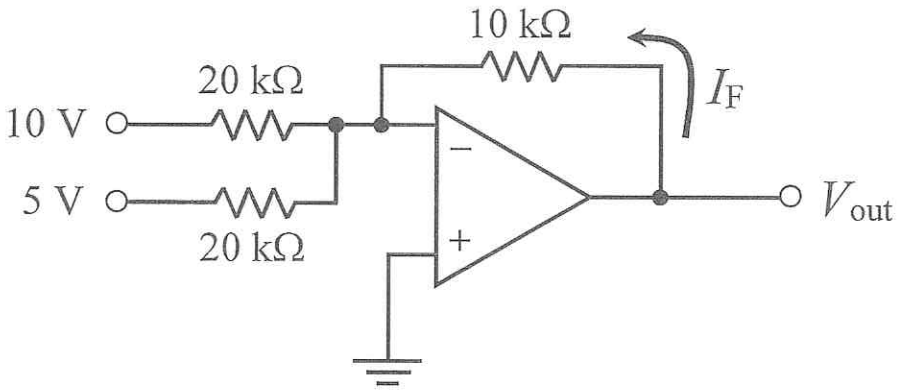

Figure Q1(a)

(c) Derive the mathematical expression of the output voltage V_o, in terms of the input voltages V_1 and V_2 for the ideal difference amplifier shown in Figure Q1(b). [6 marks]

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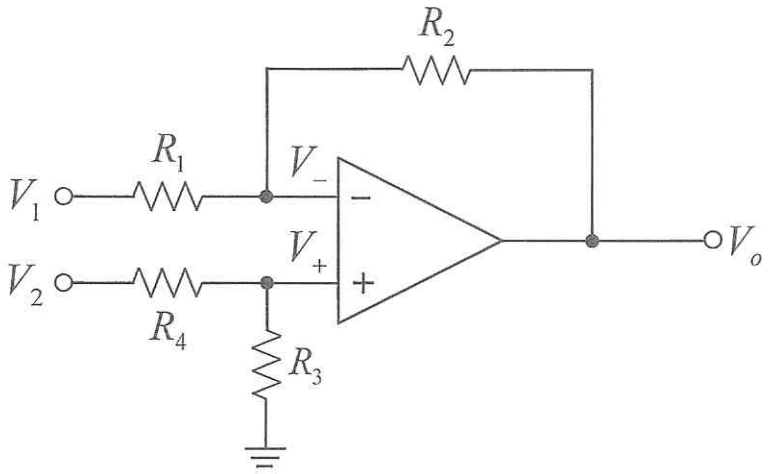

Figure Q1(b)

Question 2

(a) List and describe the **THREE** main stages which form the internal structure of an integrated circuit (IC) op-amp. [2+3 marks]

(b) A μA741 op-amp circuit operating in the inverting configuration has a closed-loop voltage gain of $A_v = -(R_2 / R_1)$, with $R_1 = 2$ kΩ and $R_2 = 300$ kΩ. The DC supply voltages change from ±15 V to ±12 V. The electrical characteristics of the μA741 op-amp at a standard room temperature of 25°C are given as follows:

Parameter	Value
Input offset voltage, V_{io}	8 mV
Input biasing current, I_B	200 nA
Input offset current, I_{io}	100 nA
Power supply rejection ratio, *PSRR*	150 μV/V
Thermal voltage drift, D_v	15 μV/°C
Thermal biasing current drift, D_b	0.5 nA/°C
Thermal input offset current drift, D_i	0.5 nA/°C

(i) The effect of the input bias current I_B can be eliminated by introducing a bias-compensation resistance R_x to the op-amp circuit. Draw the schematic diagram of the op-amp circuit. [3 marks]

(ii) Calculate the value of R_x. [2 marks]

Continued .....

(iii) Find the input offset voltage V_{io} at a temperature of $T = 55°C$. [4 marks]

(iv) Determine the total output offset voltage V_{oo} at $T = 55°C$. [5 marks]

(c) Figure Q2(a) depicts a non-inverting amplifier circuit, with $R_i = 10\ k\Omega$ and $R_f = 90\ k\Omega$. The op-amp has a unity-gain bandwidth of 10 MHz and a slew rate of 0.8 V/μs, and is biased at ±15 V. The signal bandwidth is 80 kHz.

(i) Determine the maximum closed-loop gain. [2 marks]

(ii) Find the maximum peak output voltage. [2 marks]

(iii) For the input signal v_{in} as shown in Figure Q2(b), sketch the output voltage versus time. [2 marks]

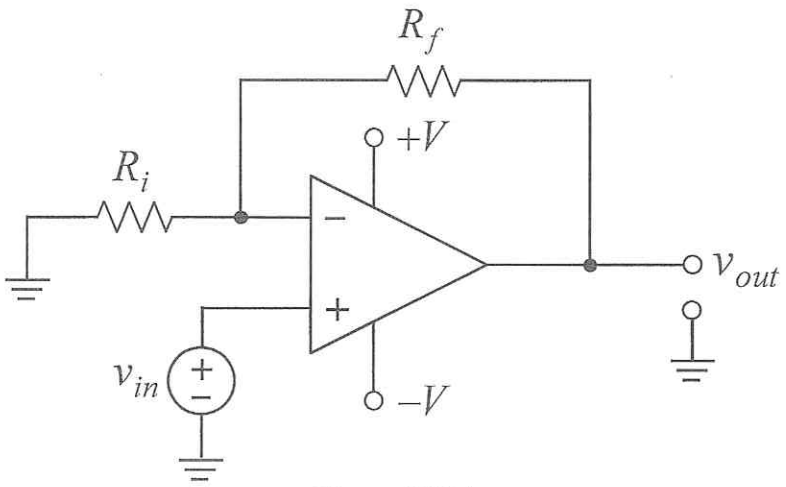

Figure Q2(a)

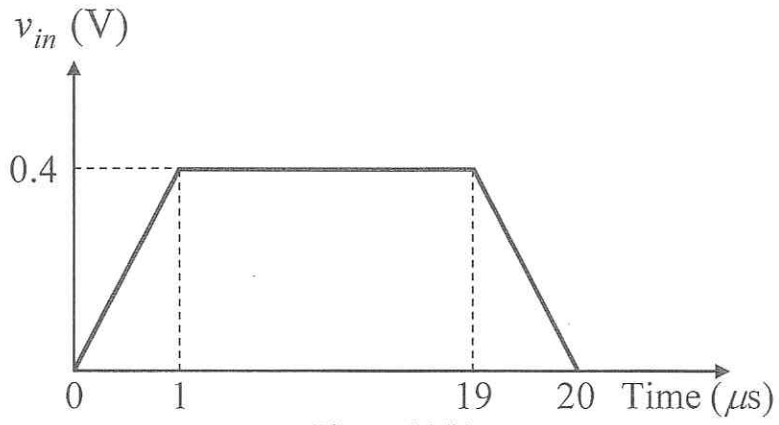

Figure Q2(b)

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Question 3

(a) The unregulated power supply, V_S in Figure Q3(a) has a voltage of 12 V at full load condition. The current limiting circuit is to operate when the pass transistor current exceeds 200 mA. Given $R_1 = 1$ kΩ, $R_2 = 680$ Ω, $R_4 = 10$ kΩ and $V_Z = 5.1$ V. Determine the following:

(i) The value of R_3 for a regulated output voltage of 9 V. [4 marks]

(ii) The required value for R_{CS}. [2 marks]

(iii) The load current when the output terminals are short-circuited. [3 marks]

(iv) The power dissipation in the pass transistor Q_1 at output short-circuited. [4 marks]

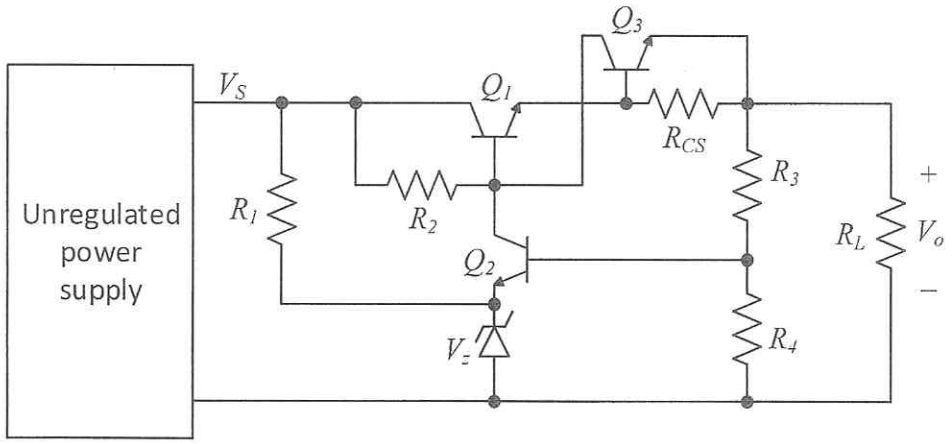

Figure Q3(a)

(b) A phase-shift oscillator circuit is shown in Figure Q3(b), where its feedback voltage gain, β is given as:

$$\beta = \frac{R^3}{R^3 - 5R\left(\frac{1}{\omega C}\right)^2 + j\left[\left(\frac{1}{\omega C}\right)^3 - \frac{6R^2}{\omega C}\right]}$$

Assume the op-amp is ideal.

(i) From the Barkhausen Criterion, derive the formula for oscillation frequency, f_o. [4 marks]

(ii) Determine β and the required amplifier gain, A for oscillation. [4 marks]

Continued .....

(iii) Determine the value of R and C for the circuit with oscillation frequency, f_o = 800 Hz, and $R_F = 100\ \text{k}\Omega$. The voltage gain magnitude of the amplifier should be 3% higher than its minimum value for oscillation.

[4 marks]

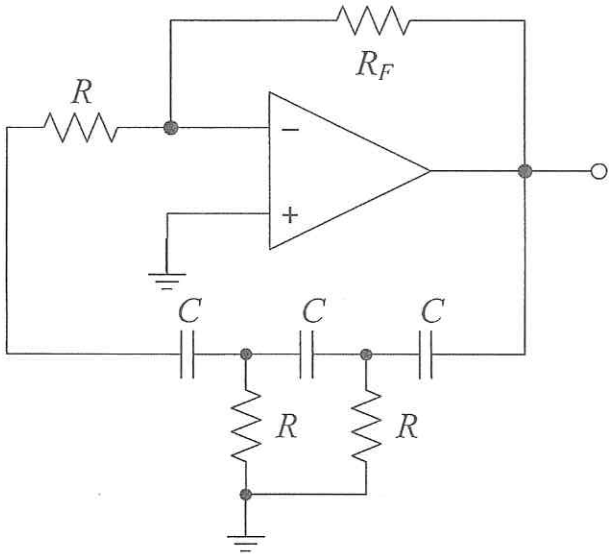

Figure Q3(b)

Question 4

(a) Figure Q4(a) shows a comparator circuit. An input signal depicted in Figure Q4(b) is applied to the non-inverting input of the op-amp. The comparator has a maximum output voltage level of ±14 V.

(i) Draw the output signal showing its **EXACT** relationship to the input signal.

[8 marks]

(ii) Determine the reference voltage, V_{ref} if $R_1 = 22\ \text{k}\Omega$ and $R_2 = 3.3\ \text{k}\Omega$.

[3 marks]

(b) A band pass filter has a quality factor, $Q = 2$, bandwidth, BW = 20 kHz. Calculate:

(i) Center frequency, f_o [1 mark]

(ii) Lower cutoff frequency, f_L [4 marks]

(iii) Upper cutoff frequency, f_H [3 marks]

Continued .....

(c) The cutoff frequency of a 3rd order Butterworth low pass filter is given as 30 kHz, and the given voltage gain, $|A|$ is given as -20dB below its maximum value. Calculate the corresponding frequency, f. [6 marks]

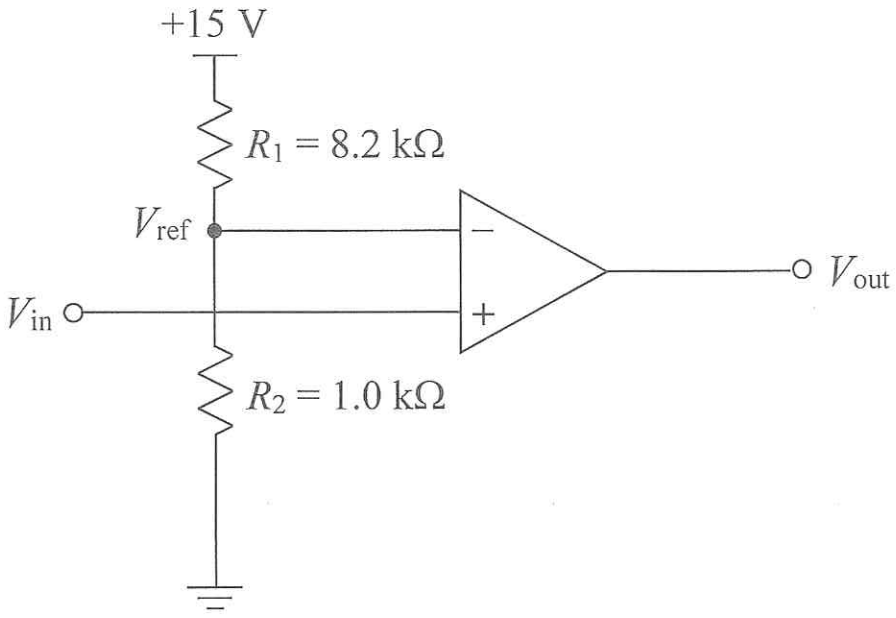

Figure Q4(a)

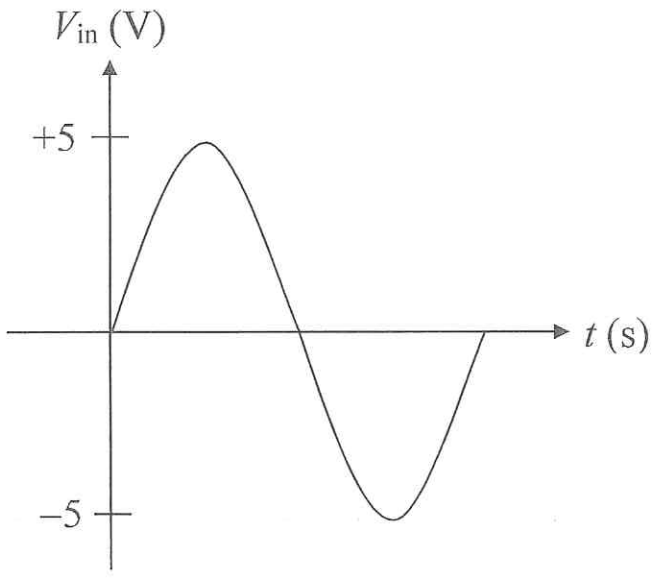

Figure Q4(b)

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